

## RECENT EXPLORATIONS IN THE ST. PAUL KARST (PALAWAN, PHILIPPINES)

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The Philippine Archipelago hosts several interesting karst areas. One, in particular, is well known because in 1999 it has been included in the UNESCO World Heritage List. The area is located in eastern Palawan, and hosts the Puerto Princesa Subterranean River (former St. Paul Subterranean River). This karst area is located between Ulugan Bay and St. Paul Bay, ~50 km NE of Puerto Princesa, the capital city. The karst covers an area of ~35 km<sup>2</sup> and is made up of a massive to roughly stratified, micritic, light to dark grey colored, lower Miocene limestone showing levels rich with fossils.

The cave, more than 24 km long, is composed of an active level and huge fossil branches; it represents a unique phenomenon, due both to the variety of its ecosystem and to its peculiar hydrodynamic features. Its outflow is about 200 m from the coast line, and tides push their influence as much as 6 km inside the cave, so that its underground river is the site of a huge mixing phenomena between fresh river water and salty sea water. In 1973 the active level of the cave was explored by Balasz, who compared the St. Paul karst to the “Yangshuo type karst” of southern China, featured by extremely steep positive shapes known as “towers”.

The cave, was explored by Australian teams in the early 1980s, and then explored over the course of several expeditions beginning in the late 1980s by the association La Venta and the Italian Speleological Society. In 2007 and 2008, in collaboration with the authorities of the park and the city of Puerto Princesa, La Venta organized two expeditions to this karst area. The project aimed at completing the exploration of the underground river, reaching and exploring some dolines on the NW side of the mountain, surveying the SE part of the area, and trying to reach the top area of Mount St. Paul (1028 m asl).

In the course of the two expeditions several kilometers of new active and fossil leads were explored and mapped in the Puerto Princesa Subterranean River. Three vertical caves were explored in the NE area, one of which is now the deepest one in the archipelago. Three huge relict through-caves were explored and mapped in the SE portion. In attempting to reach, or even approach, the top of Mount St. Paul, the surveys demonstrated the great difficulties of working in this kind of terrain.

## 1. Introduction

The Philippine Archipelago hosts several interesting karst areas. One, in particular, is well known because in 1999 it has been included in the UNESCO World Heritage List. The area is located in eastern Palawan, and hosts the Puerto Princesa Subterranean River (PPSR) (Piccini, 2007).

The outflow of the cave has always been known to local people, and the first explorers were probably pushed to enter the cave searching for drinkable water and swallows' nests. Some writings left by visitors in the first part of the cave bear the dates of April 13th, 1937 and June 20th, 1966, but, as far as we know, the first documented exploration of the underground river was carried out by Balasz (1973). Some years later two Australian expeditions (Traditional Explorations and the Sidney Spel. Soc., in 1980, and

Environment Studies Ass. of Virginia, in 1982) surveyed the whole length of the main trunk to a second entrance, the so-called “Day-light Hole”. The Australian cavers also discovered a third entrance following a long left affluent. At the end of these expeditions the total length of the cave was 8.2 km.

In 1989, Italian cavers explored the huge gallery levels above the river and some side branches (De Vivo et al., 1990). In the course of the expedition ca. 5.7 km of new passages were explored and the whole cave was re-surveyed. The following year a small group of Italians went back to St. Paul to continue the exploration of the fossil levels. In 1991, besides carrying out geological and biological studies, almost 3 more km of new galleries were explored. These last explorations brought the total development of the system to more than

20 km (Piccini & Rossi, 1994).

In May 2000 La Venta association supported the production of a documentary, "The River of the Swallows", produced by the Italian *Paneikon* together with Italian network RAI 3 and French *La Cinquième*. The documentary was awarded the first prize at the Film Festival of the International Speleological Congress of Brasilia 2001 and the Grand Prix at the Speleovision 2002 Film Festival.

Finally, in 2007 and 2008 the La Venta Esplorazioni Geografiche association reprised the study of the karst system, extending the investigation to the external slopes of the St. Paul ridge. Several caves were discovered and explored testifying the relevant potential of this karst area. Most of these caves are ancient relict caves which indicate a long and complex speleogenetic history (Piccini et al., 2007).

In this paper a short description of recent discoveries is reported

## 2. Geographical and Geological Overview

The island of Palawan is the fifth most extended island of the Philippine archipelago; it has a long and narrow form and is predominantly mountainous along its entire length. The portion to the NE of Ulugan bay is bordered to the W by a N-S strike-slip fault, which transects the whole island. The karst areas are mainly developed in Cenozoic carbonate formations and are present in the southern part of Palawan as well as in the N, notably in the area of El Nido which has an amazing coastal tower karst.

The Mount St. Paul ridge, 1028 m high, covers a surface of around 35 km<sup>2</sup> and is made up of massive, dark grey micritic limestone

of the Late Oligocene - Early Miocene eras. This formation, thicker than 500 m, rests on Oligocene mudstones, sandstones, marls and volcanites. The carbonate outcrop takes the form of a long ridge running NE-SW, bordered by the Babuyan river valley to the E and the Cabayugan river valley to the W. This structure can be approximately described as uniclinal, dipping to the NW, bordered by faults.

On most of the eastern and southern sides, the limit of the calcareous rocks corresponds to the base of rocky cliffs, which can reach 300 m. Such a structure allows the karst system to receive allogenic water only from the W, along the Cabayugan valley, with the exception of the extreme northern part, where small marginal closed basins are drained by swallow-holes on the eastern slope (Fig. 1). The Cabayugan River is absorbed at a height of ~30 m above sea level, and it flows through the St. Paul cave, re-emerging

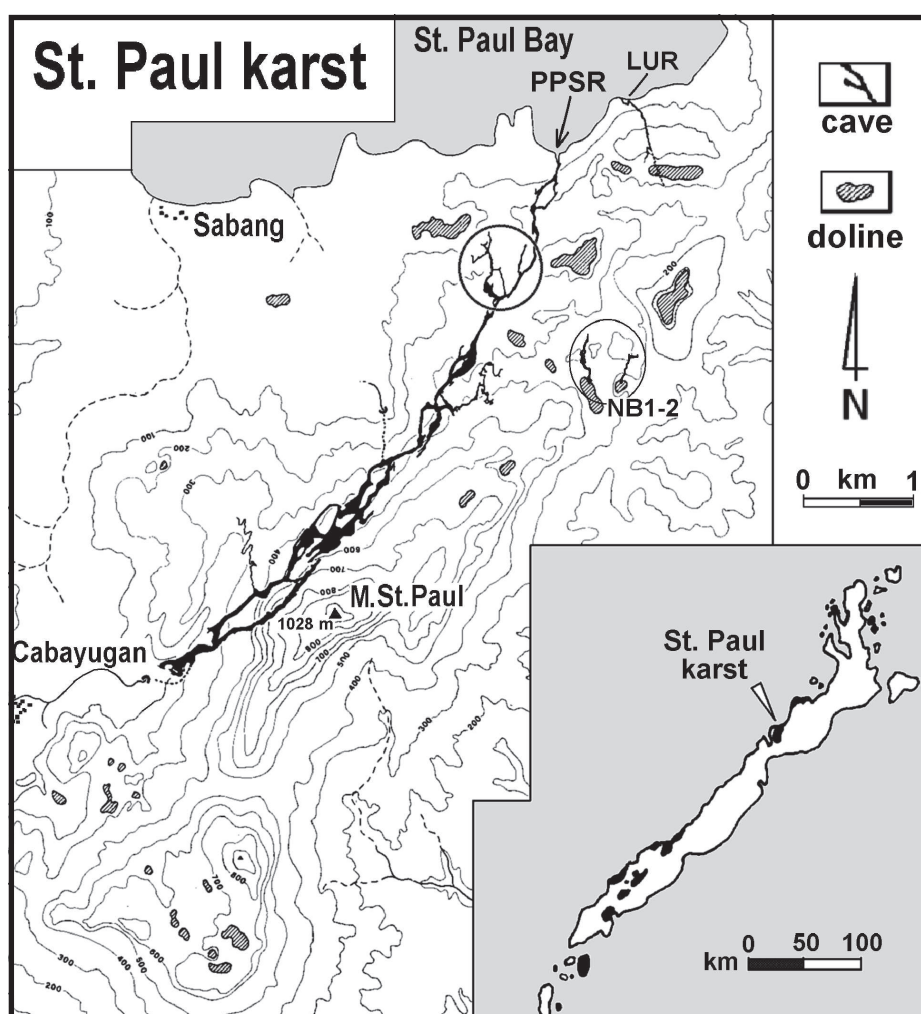


Figure 1: Sketch map of the St. Paul karst area with the location of major caves; circles indicate recent explorations. PPSR – Puerto Princesa Subterranean River, LUR – Little Underground River, NB1-2 – Nagbituka Caves 1 and 2.

on the coast. Beyond the sinking point, the valley is active during the rainy season and shows secondary losses along the edge of the karst. The karst exhibits a typical tower and cockpit landscape.

### 3. The Puerto Princesa Subterranean River

This large cave system consists of a main axis, which runs NNE-SSW for about 8 km, formed by a large gallery through which the underground river flows, connecting the Cabayugan swallow-hole with the resurgence on the coast. The main gallery has several branches and a few small tributaries, mainly from the left; the main one is the Australian Inlet, which comes from a depressed area slightly to the S of Sabang. On the right side there is only one tributary worth noting, which originates from a brief side passage closed by a sump. The parallel branches extend mainly to the left of the main drain, in its central and southern portions. The largest of these galleries (Cin Gallery) was discovered and explored in 2007. Some of these passages are reactivated during floods, as indicated by the presence of alluvial deposits. In the downstream part of the underground river, some parallel galleries form a sort of ramified network, typical of the estuary's inter-tidal zones.

The main branches are found above the current active course and are segments of an ancient pathway of the underground river, now broken up by collapses or in-fills. The elevation of these galleries, which are generally larger than the current collector, varies from 50 to 100 m a.s.l. Many sections have, however, been affected by collapse, which have increased their size as well as raising the level of floors and ceilings. The largest rock-falls have created a large chamber, called the Italian's Chamber, which is 360 m long, reaches a maximum width of 140 m and a height of 80 m, with an estimated volume of ~2.5 million cubic meters.

One of the most significant hydrodynamic features of the cave is undoubtedly the fact that tides push their influence as much as 6 km inside it, so that it is a site of huge mixing phenomenon between fresh river water and salt sea water. Looking at it in this way, the system may reasonably be considered the world's most classical example of an underground estuary (Forti et al., 1993). From a hydro chemical point of view the St. Paul cave may be subdivided into two different dominions: one, upstream from the Rockpile, characterized by the presence of fresh rain water, showing few, limited mixing effects with salted waters and a constant water flow from upstream to downstream; the other one, from Rockpile to the sea, characterized by mighty mixing effects, by flow direction inversions and by marked vertical variations in salt content (Forti et al., 1993).

### 4. Recent explorations

#### 4.1 Puerto Princesa subterranean river

*Cin Galleries* (length 1750 m) - This was the most important discovery made in the PPSR during the 2007 campaign. The main gallery is reached through a flooded branch passage, beginning around 1.5 km from the entrance on the left hydrographic side of the main tunnel. The flooded tract is a small size gallery, with a short low passage that is completely closed when the tide is high. Beyond this tract, a wide gallery with a sandy floor is reached, which runs parallel to the main collector. To the S, the gallery continues among large concretion deposits and sand and mud in-fills, and finally reaches a chamber connected to the Navigator's Chamber. Towards the N, the gallery continues wide for ~200 m and then splits into two branches.

*"Frangose" Galleries* (length 300 m) - The gallery starts a few dozen meters downstream from the entrance of the Cin Galleries. After an initial narrow stretch and two short drops, the gallery becomes larger and assumes collapse morphology for 100 m, then reduces in size and finally closes on in-fills.

*Old River Gallery* (length 400 m, vertical range +98 m) - This branch begins on the hydrographic right, about 700 m from the entrance, in the second chamber upstream along the river. It is reached by climbing the rock wall and its overhanging slope of mud and debris for a total height of 50 meters. At the summit a large room with an alluvial terrace shows the levels deposited by the ancient course of the river. From the edge of the balcony, an ample rectilinear gallery, with a triangular section about twenty meters wide, goes on to the S for 70 meters. A slight ascent gives access to a new section characterized by cemented rockfalls that extends ESE for another 50 m.

#### 4.2 The southern sector of the St. Paul Ridge

The extreme southern part of the Mt. St. Paul ridge is characterized by two polygonal mountains, separated from the main ridge. The two elevations have a summit surface, enlivened by long, deep depressions and great sinkholes, whose average altitude is ~500 m for the westerly one, and ~700 m for the easterly one. The two upper surfaces are bordered by steep slopes and cliffs, up to 300 m high.

The two areas are difficult to access and during the 2007 expedition, only the western high, overlooking the village of Cabayugan, was explored, although the other one had many cave entrances, which were observed from the helicopter. The elevation of the area goes from 40 m, which corresponds to the alluvial plain to the NW, to the peak at 615 m at the

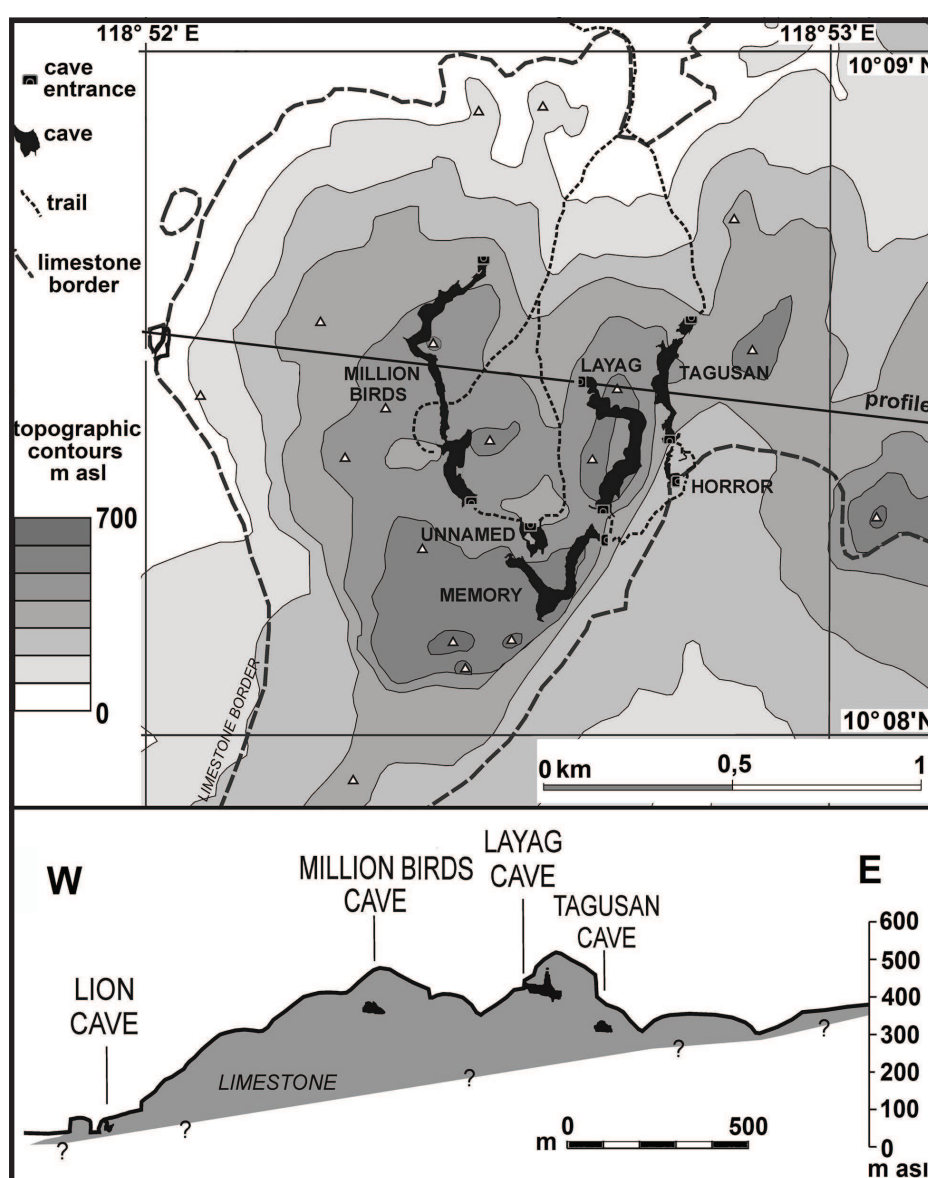


Figure 2: Sketch map of the southern sector of the investigated area, a few kilometers S of Cabayugan, showing the plan development of major caves.

southern extremity of the mountain. In this area six caves were surveyed (Fig. 2). One of these caves, called Horror Cave, is an active swallow-hole that absorbs the waters of a small basin. The other five caves have similar morphological characteristics and consist of large crossing galleries that connect the major depressions, at the centre of the relief, with the external slopes.

*Horror Cave* (length 220 m, depth: - 64 m) - This is the only cave of the Cabayugan karst area containing an active course of water. The cave is also set apart from all the other known cavities for the smaller size of its conduits and for its morphological features. The entrance is at ~200 m a.s.l., at the bottom of an elongated basin in which Oligocene sandstones appear on the surface, and consists of a

rectangular portal about 20 m wide and 4 m high at the base of the calcareous wall which closes the depression to the NW.

*Tagusan Cave* (length 515 m, depth - 27 m) - The cave is a natural passage which connects the bottom of two incisions running from S to N under the saddle that separates two cones and its name, "tagusan", means "tunnel." The floor of the cave entrance is an accumulation of debris at least 10 m high, beyond which one continues into a gallery 25-40 m wide and 25-30 m high. The gallery contains large and degraded columns and stalagmites.

*Memory Cave* (length 580 m, depth -38 m) - This cave opens with a portal 15 m high and 25 m wide, on a steep calcareous slope, in the midst of the forest, at an altitude of 360 m. After descending the accumulated debris at the entrance, we intersect a large gallery. The dimensions are impressive, with widths of 25-30 m and

heights of 30-40 m. Large blocks, debris, accumulations of guano, columns and stalagmites, which are often heavily corroded, characterize the tunnel. The walls are in places covered with concretions. The gallery seems to extend beneath the narrow valley that separates two karst cones, after about 200 m nearly reaching the surface at the level of a vast depression on the outside. From here, with a sudden 90° turn, the gallery continues for other 180 m, ending with large concretion masses.

*Layag Cave* (length 550 m, elevation range - 30, +20 m) - A few dozen meters above the entrance of Memory Cave, the gigantic S portal of Layag Cave opens in the right (NE) cliff. The large entrance is raised over an accumulation of collapsed blocks over 15 m high. For more than 400 m



the gallery goes on ~40 m wide and ~50 m high, the floor covered with large collapsed blocks. The collapses have deeply modified the conduit giving rise to a huge tunnel with an arched transversal section. After almost 400 m, a pit opens on the right hand wall, which is inhabited by a colony of bats, probably the most numerous of this area. After skirting a large rock pillar, one arrives directly beneath an entrance, situated 70 m above the floor, originating from the progressive collapse of the vault. Further ahead one enters a narrower gallery, which after less than 100 m reaches the outside through a portal about ten meters wide and high, which directly faces out from the cliff towards the Cabayugan plain.

*Million Birds Cave* (length 1150 m, depth -43 m) - The cave opens at the bottom of a large depression. Once past the usual large accumulation of debris and blocks at the entrance, the gallery reaches a width size of 30-40 m (Fig. 3). 120 m further down it emerges from the slope on the other side of the crest, at the bottom of another karst depression. The gallery continues N for another 700 m, reaching a new exit. The gallery is 20-30 m high and generally ~20 m wide, with walls often covered by the black vertical stripes of oxide crusts, deposited by waters that percolated along the walls. The cave owes its name to the colonies of swallows and bats that populate it, a phenomenon which takes place in all the caves of the Mount Saint Paul area.

*Unnamed cave* (length 150 m, depth -36 m) - In the same depression in which Million Birds Cave opens, another large cavern that has no local name is to be found, with a large portal 50 m wide and 25 m high. The entrance floor is the top of a large accumulation of debris at the base of which we reach the floor of the cavern among debris, accumulations of guano, and large collapsed stalagmites. Concretions are generally degraded.

#### 4.3 The northern zone

Steep slopes and calcareous cliffs characterize the eastern side of the St. Paul ridge. Toward the N, the morphology becomes less accentuated and one observes an area characterized by deep depressions that mark the limit of the calcareous outcrop. These depressions, the largest of which is over 2 km wide, have several swallow-holes at their bottom, which are frequently active during the dry season and which feed smaller karst systems parallel to the PPSR. In this area only a rapid survey was made, which has verified the existence of several caves and the exploration of two of them named Nagbituka 1 and Nagbituka 2.

*Nagbituka 1 Cave* (length 650 m, depth -270 m) - The cave opens inside a small depression furrowed by water and is an active swallow-hole (Fig. 4). The entrance is rather small. After a small collapsed area at the entrance, the cave continues with small jumps, and steep passages along the

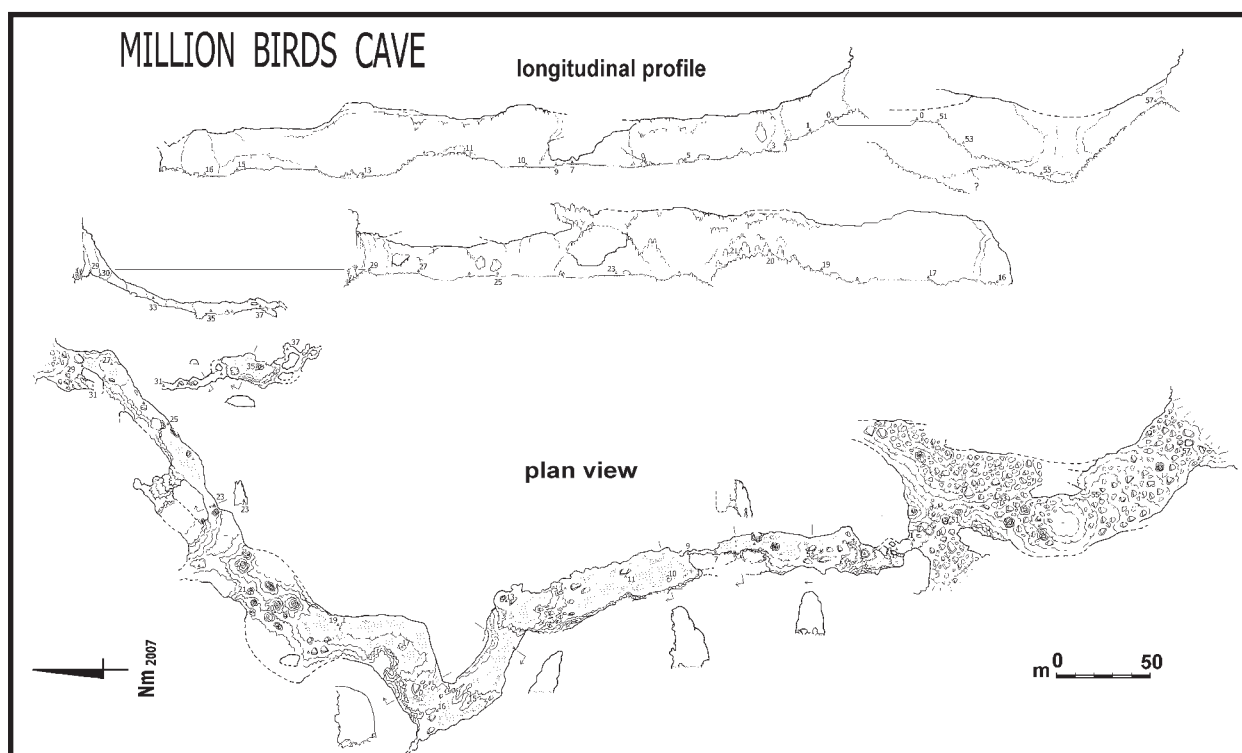


Figure 3: Longitudinal profile and plan view of Million Bird Cave (survey: E.G. La Venta, 2007–2008).

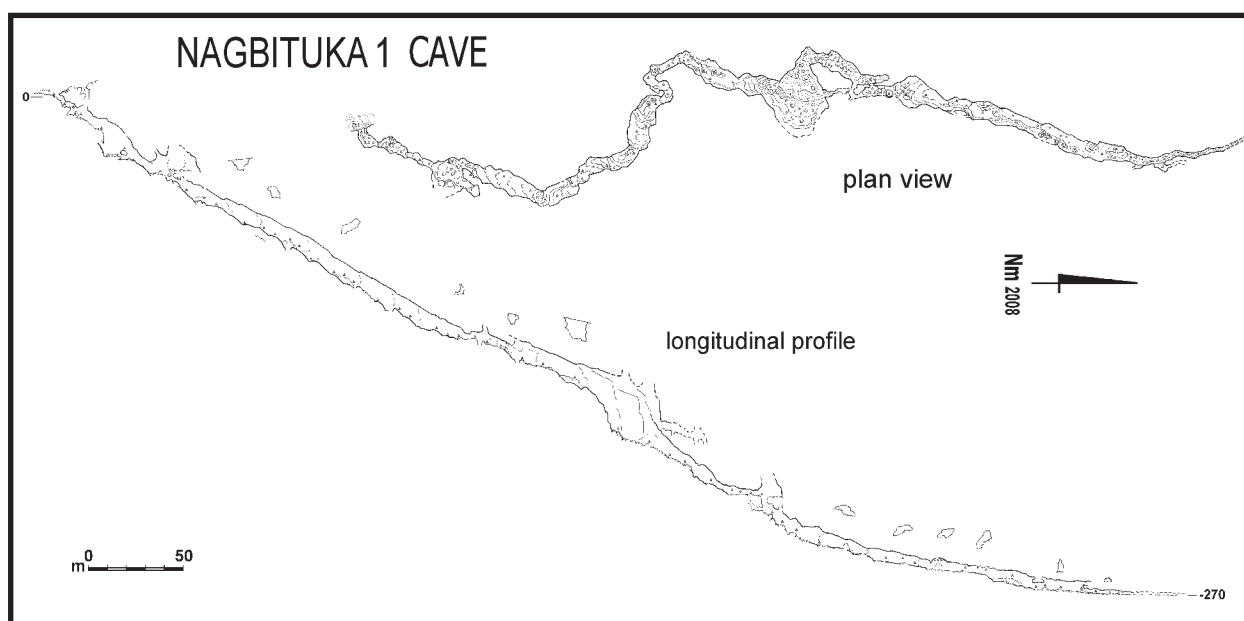


Figure 4: Longitudinal profile and plan view of Nagbituka 1 Cave (survey: E.G. La Venta, 2007–2008).

contact with the sandstone. Continuing for about 30 m meters, a narrow side passage gives way to a large chamber, around 15 m wide. A few meters before this, a small deviation leads to a new fracture, parallel to the first one, which continues descending along the geological contact between limestone and quartz sandstone for a further 100 m. The inclination remains constant, while the water flows in steep passages. Finally, the stream falls down into a large and high chamber with a 40 m waterfall. Descending a steep boulder slope on the left of the chamber we achieved a lower tunnel which continues with minor dip, reducing progressively in dimension. The cave ends with a low and

flooded passage just a few meters above the sea level.

*Nagbituka 2 Cave* (length 500 m depth -132) - The entrance is located some hundreds of meters N of Nagbituka 1, at the bottom of a large doline, and it acts as an active swallow (Fig. 5). After the first small drops, the cave reduces its dimension to a low and narrow passage that is probably completely water filled during the rainy season. A narrow steep passage opens newly on a large descending tunnel, which can be climbed down for ~300 m up to a small pit, which is filled with mud at the bottom. Just a few meters before the rim of the pit, a secondary branch starts with

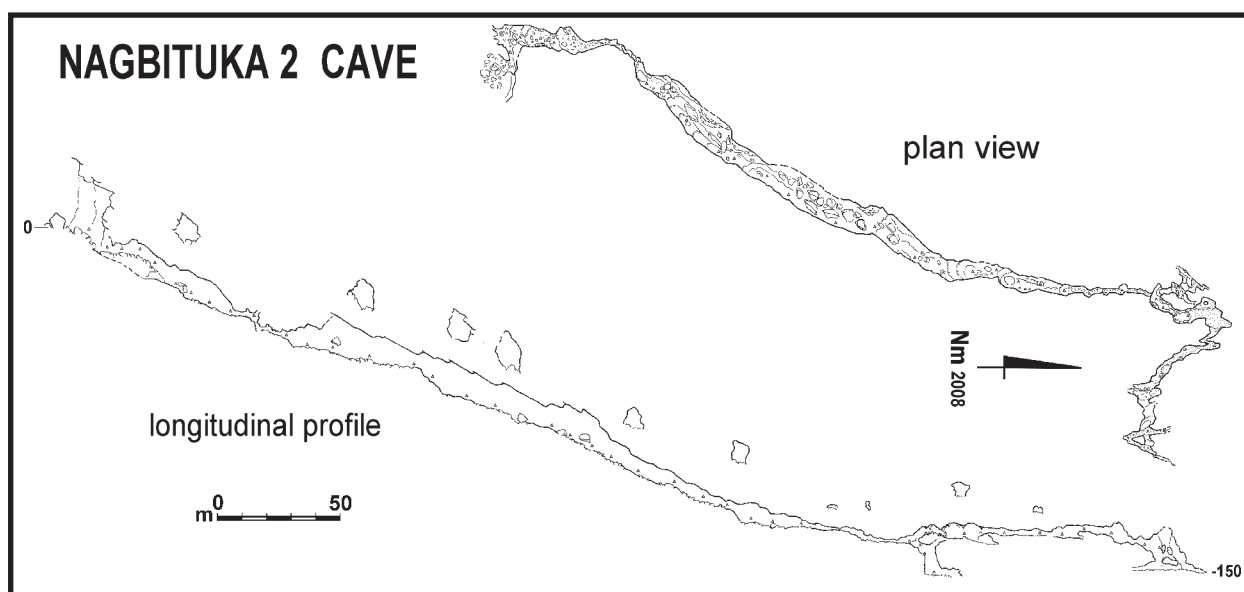


Figure 5: Longitudinal profile and plan view of Nagbituka 2 Cave (survey: E.G. La Venta, 2008).

Name	Elevation m a.s.l.	Vertical range m	Length m
Puerto Princesa Subterranean River	0	+ 100	24000
Little Underground River	0	+ 10	ca. 800
Nagbituka 1 Cave	290	- 270	650
Nagbituka 2 Cave	250	- 132	500
Lion Cave (lower S entrance)	50	+ 15	182
Tagusan Cave (South Entrance)	305	- 12, +15	515
Horror Cave	205	- 64	183
Layag Cave (S entrance)	405	- 40	583
Memory Cave	365	- 38	580
Millionbirds Cave (S entrance)	410	- 43	1150
Unnamed Cave	400	- 35	112

Table 1: Lengths and depths of explored caves.

a dry and beautiful gallery with several concretionary formations. The gallery represents an old phreatic level and reaches again the active pathway after a length of ~100 m. The stream enters a narrow passage that could not be passed due to the presence of much water.

## 5. Conclusions

St. Paul karst is surely one of the most relevant and still promising speleological areas of the Philippines (Table 1).

The PPSR can be considered as a well explored cave although many minor branches have to be further investigated. The most promising areas are, however, the N and the S sector of the mountain ridge, where many new cave entrances are visible by over-flying the area and on aerial photos. Unfortunately the extreme roughness of the surface, characterised by high and sharp limestone blades, has not yet allowed a complete recognition of the two areas.

## Acknowledgements

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## References

Balazs D., (1973) Karst Types in the Philippines: Proc. of the 6th International Congress of Speleology, vol. II, Praha 1976, 13-38.

De Vivo A., Piccini L., Mouret C. (1990) Macatingol: il fiume che romba. *Speleologia*, Società Speleologica Italiana, 22, 22-31.

Forti P., Piccini L., Rossi G., Zorzin R. (1993) Note

preliminari sull'idrodinamica del sistema carsico di St. Paul (Palawan, Filippine). *Bulletin Société Géographique de Liege*, 29, 37-44.

Hashimoto, Sato, Tadashi. (1973) Geologic Structure of North Palawan and its bearing on the Geological History of the Philippines. *Geology and Palaeontology of Southeast Asia*, v.13, 145-161.

Piccini L. (2007) Una grotta tra terra e mare (A cave between land and sea). *Kur magazine*, La Venta Esplorazioni Geografiche, 9, 16-23.

Piccini L., Mecchia M., Bonucci A., Lo Mastro F. (2007) Nuove esplorazioni speleologiche nel carso di St. Paul (Recent speleological explorations in the St. Paul karst). Suppl. *Kur magazine*, La Venta Esplorazioni Geografiche, 9, p. 12.

Piccini L., Rossi G. (cur.) (1994) Le esplorazioni speleologiche italiane nell'Isola di Palawan, Filippine - Italian caving exploration in the island of Palawan, Philippines. *Speleologia*, Società Speleologica Italiana, 31, 5-61.

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